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Synergistic Effects of Modified Atmosphere Packaging and Antioxidants on Chilling Injury and Storage Life of Guava

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ABSTRACT

An experiment was done to decrease the chilling injury and increase the shelf life of guava by synergistic effects of antioxidants and modified atmosphere packaging . In this study fruits were dipped in 50 ppm benzyl adenine, 0.1, µM methyl jasmonate, 500 ppm thiabenzadole and 6 mmol oxaloacitic acid with 2,4 pores modified atmosphere packaging. Observed the chilling injury and storage life of guava cv.Allahabad safeda stored at 6+1 ^{0}C.This experiment was conducted at fruit research station ,Sangareddy, Medak district,Telangana. The experiment was done by using completely randomized design with factorial concept with three replications per treatment. Guava fruits cv.Allahabad safesda were dipped in antioxidants and packed in polypropylene bags, stored at 6+1^{0}C. Among all the treatments Fruits dipped in 50ppm benzyl adenine and packed in 4 pores polypropylene bags, significantly recorded lowest PLW. Significantly highest fruit firmness and organoleptic evaluation were recorded with fruits dipped in 50 ppm benzyl adenine and packed in 4 pores polypropylene bags. Significantly lowest chilling injury and electrolyte leakage was recorded in fruits dipped in 50ppm benzyl adenine and packed in 4 pores polypropylene bags, corresponding increase the shelf life of upto 29.45 days .The fruits kept under control recorded a shelf life of 20 days only. Titratable acidity was significantly lowest in fruits dipped with 50ppm benzyl adenine and packed in 4 pores polypropylene bags .Fruits dipped in 50ppm benzyl adenine and packed in 4 pores polypropylene bags recorded significantly highest TSS, Brix-acid ratio and ascorbic acid.

Key words: *Guava, Benzyl adenine, Methyl jasmonate, Thiabendazol and Oxalixc acid,Chilling injury and MAP*

INTRODUCTION

Guava (*Psidium guajava* L.) the "poor man's fruit" and "apple of tropics" is a popular tree fruit of tropical and sub tropical climate and is native to the Tropical America stretching from Mexico to Peru. It belongs to the family *Myrtaceae* and has recognition of being the most widely cultivated species of this family.

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In India postharvest losses of fruits and vegetables are estimated to be 30-35 per cent which amount to losses to the extent of Rs 3000 crores[15]. Modified atmosphere packaging is a preservation technique used to prolong the shelf life of processed or fresh food by changing the composition of the air surrounding the food in the package. Modified Atmosphere Packaging (MAP) refers to the development of a modified atmosphere around the produce through the permeable polymeric films[11] and MAP had been reported to maintain the quality of several tropical fruits[7]. It is an inexpensive method compared to CA storage and transport and therefore, it had been suggested as an alternative to shipping in MA/CA[14]. Kader[11] recommended 2-5% O_2 and 0-1% CO_2 for CA storage of guava at 5-15^{0}C , modified atmosphere storage can extend the storage life of many tropical and sub tropical fruit. Antioxidants help in extending the shelf life of fruits. These are the compounds which prevent the free radical formation and cell membrane disintegration which occurs by lipoxygenase and lipid peroxidation reactions. These compounds could extend the shelf life of fruits by minimizing the onset of ripening and ethylene production which is mediated by lipid peroxidation reactions. Various commercial antioxidants are being used in post harvest sectors as well as in food industries, like benzyl adenine, oxalic acid, methyl jasmonate and thiabendazole etc. These antioxidants will prevent or delay the formation of free radicals and different degenerative pathways like lipoxygenase reactions which would enhance the production of ethylene that may lead to the ripening[17].

MATERIAL AND METHODS

The experiment was carried out during 2013-14 at Fruit Research Station, Sangareddy, Medak. Allahabad Safeda is the cultivar used, experiment consists of nine treatments in three replications (details presented below) with forty five units per replication was laid out in completely randomised design with factorial concept. Dipping time is five minutes and temperature of 6±1^0 C was maintained during storage. Each treatment was evaluated at five days interval. Data recorded was subjected to statistical analysis as outlined by Panse and Sukhatme[17].

Details of treatments

T_1- MAP with 2 pores + Dipping of fruits in BA 50 ppm
T_2- MAP with 2 pores + Dipping of fruits in MJ 0.1 µM
T_3 - MAP with 2 pores + Dipping of fruits in TBZ 500 ppm
T_4 - MAP with 2 pores + Dipping of fruits in OA 6 mmol
T_5 - MAP with 4 pores + Dipping of fruits in BA 50 ppm
T_6 - MAP with 4 pores + Dipping of fruits in MJ 0.1 µM
T_7 - MAP with 4 pores + Dipping of fruits in TBZ 500 ppm
T_8 - MAP with 4 pores + Dipping of fruits in OA 6 mmol
T_9 – Control.

RESULTS AND DISCUSSION

Physiological loss in weight (%)

The treated fruits differed significantly (table 1) with highest PLW (3.47) in fruits kept under control. Lowest (1.80) PLW was recorded in fruits packed in polypropylene bag with 4 pores + fruits dipped in 50 ppm benzyl adenine. There were significant differences in PLW among different days of storage period. The PLW increased from 1th day (0.68) to 25th day (3.58). The increase was more pronounced from 10th day (1.48) to 15th day (2.45). Among all treatments, fruits kept under control recorded highest PLW except 5th day of storage. On 5th day lowest PLW was recorded with fruits packed in polypropylene bags with 4 pores + fruits dipped in 50 ppm benzyl adenine. On 5th to 25th days, fruits packed in polypropylene bags with 4 pores + fruits dipped in 0.1 µM methyl jasmonate and fruits packed in polypropylene bags with 4 pores + dipping of fruits in 500 ppm thiabendazol recorded on par with one and other. The high relative humidity in MAP packing[1] and reduced senescence, rate of respiration, ethylene production and ripening of fruits by antioxidants[5] might have resulted in reduced PLW.

Fruit Firmness (kg.cm^{-2})

Results presented in table 2 reveal that treated fruits differed significantly with highest fruit firmness (6.18) in fruits packed in polypropylene bag with 4 pores + fruits dipped in 50 ppm benzyl adenine. The lowest (4.62) fruit firmness was recorded in fruits kept under control. The fruit firmness decreased from 1st day (8.30) to 25th day (2.61). The decrease was more pronounced from 20th day (4.49) to 25th day (2.61). Among all treatments, fruits packed in polypropylene bag with 4 pores + fruits dipped in 50 ppm benzyl adenine recorded the highest fruit firmness on 1st day and this pattern of highest fruit firmness was maintained by this treatment on all intervals of storage, while lowest fruit firmness was recorded in fruits kept under control. Reduced nature of ripening of antioxidant treatments[9] of the fruits might have resulted in higher fruit firmness in the present study Khumbhar and Desai[13] and Berger *et al*[3].

Chilling Injury (Skin scald)

Highest (3.33) chilling injury was recorded in fruits kept under control (table 3) while lowest (2.12) recorded in fruits packed in polypropylene bag with 4 pores + fruits dipped in 50 ppm benzyl adenine. Chilling injury increased from 5th day (1.09) to 30th day (3.70). The increase was more pronounced from 5th day (1.09) to 10th day (1.76). Among treatments fruits packed in polypropylene bags of 4 pores with (T_5) fruits dipped in 50 ppm benzyl adenine, (T_6) 0.1µM methyl jasmonate and (T_7) 500 ppm thiabendazol recorded no chilling injury up to 5th day of storage while the (T_5) fruits packed in polypropylene bags of 4 pores + fruits dipped in 50 ppm benzyl adenine recorded lowest chilling injury up to 30th day. However on 10th day, 15th day, 25th day and 30th days storage on par chilling injury was recorded in the (T_3) fruits packed in polypropylene bags with 2 pores + fruits dipped in 500 ppm thiabendazol which was on par with (T_4) fruits packed in polypropylene bags with 2 pores + 6 mmol oxalic acid and (T_6) fruits packed in polypropylene bags with 4 pores + 0.1 µM methyl jasmonate which was on par with (T_7) fruits packed in polypropylene bags with 4 pores + 6 mmol oxalic acid . The provision of high humidity and prevention of chilling-induced oxidative stress (Hodges *et al.* 2004) through MAP and scavenging of the reactive oxygen species (ROS) during cold storage[19] through antioxidants might have resulted in reduced chilling injury.

Electrolyte leakage (%)

The treated fruits differed significantly with highest (10.10) electrolyte leakage was recorded in the fruits kept under control (table 4). The treatments with lowest chilling injury has been recorded the lowest electrolyte leakage. The lowest (7.19) electrolyte leakage was recorded in the fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine. The electrolyte leakage increased from 1st day (4.48) to 30th day (11.22). The increase was more pronounced from 25th day (9.71) to 30th day (11.22). Among all treatments, the electrolyte leakage was increased irrespective of treatments from 1st day to 30th day of storage. However, the fruits kept under control recorded the highest electrolyte leakage on all intervals of storage. On 1st day to 30th day, the fruits packed in polypropylene bags with 4 pores + 50 ppm benzyl adenine recorded the lowest electrolyte leakage on all intervals of storage.The fruits packed in polypropylene bags with 4 pores + dipping of fruit in 50 ppm benzyl adenine stored at 6^{O} C for 30 days recorded significantly lower electrolyte leakage on all days of storage. The reduction of chilling injury during cold storage[19] in MAP packing and the scavenging of reactive oxygen species (ROS) by the antioxidant activity of benzyl adenine might have resulted in reduced electrolyte leakage

Ripening (in days)

The synergistic effect of antioxidants and modified atmosphere packaging on the days taken to ripening of guava cv. Allahabad safeda stored at 6± 1º C was presented in the Table 5. The highest (20.10) days taken to ripening was recorded in the fruits packed in polypropylene bags with 4 pores + 50 ppm benzyl adenine. The lowest (9.25) days recorded in the fruits kept under control. The retardation of fruit ripening might be due to the scavenging action of antioxidants on free radicals resulting the lower catalase activity, respiration and ethylene synthesis. This effect might also be due to the combination of MAP and antioxidants. The lower ethylene production in MAP packing (Gonzalez *et al*. 1990) and the scavenging action of free radicals and lowering the catalase activity and ethylene synthesis by antioxidants[4] might have resulted in higher days taken to ripening

Shelf life (in days)

The treated fruits differed significantly with highest shelf life (29.45) in fruits packed in polypropylene bags with 4 pores + fruits dipped in 50 ppm benzyl adenine (table 6). The lowest (20) shelf life was recorded in the fruits kept under control. Fruits packed in polypropylene bags with 4 pores + fruits dipped in 6 m mol oxalic acid (28.40) which was on par with fruits packed in polypropylene bags with 4 pores + fruits dipped in 0.1 µM methyl jasmonate (28.38) and in the fruits packed in polypropylene bags with 4 pores + fruits dipped in 500 ppm thiabendazol (28.35) stored at 6 ± 1º C. The fruits packed in polypropylene bags with 4 pores + fruits dipped in 50 ppm benzyl adenine recorded significantly highest shelf life of 29.45 days. Further, the increase in shelf life was observed in those treatments which lowered chilling injury (4.3.3) and electrolyte leakage (4.3.4).The lower chilling injury[19] , electrolyte leakage[6] in MAP packing and the scavenging of the reactive oxygen species (ROS) during cold storage[19] through antioxidants might have resulted the highest shelf life.

Organoleptic evaluation

The treated fruits differed significantly with highest organoleptic evaluation (6.43) in fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine. The lowest (5.46) organoleptic evaluation was recorded in kept under control (Table 7). The organoleptic evaluation increased from 1th day (4.08) to 25th day (6.18) and then decrease from 25th day (6.18) to 30th day (3.83). On 1st day, highest organoleptic evaluation score was recorded in the fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine which was on par with the fruits packed in polypropylene bag with 4 pores + 0.1µM methyl jasmonate ,the fruits packed in polypropylene bag with 4 pores + 500 ppm thiabendazol and the fruits packed in polypropylene bag with 4 pores + 6 mmol oxalic acid. On 1st day lowest organoleptic evaluation score was recorded in the fruits kept under control which as on par with fruits packed in polypropylene bag with 2 pores + 0.1µM methyl jasmonate. On 5th day to 30th day, highest organoleptic evaluation was recorded in fruits packed in polypropylene bag with 4 pores + dipping of fruits in 50 ppm benzyl adenine. While lowest organoleptic evaluation was recorded in fruits kept under control on all intervals of storage. The increase in organoleptic score in combination of antioxidants and modified atmosphere packaging treatments is due to the retarted ripening and softening of fruits[10] and also due to increase or maintaining the firmness of fruits by cohesive effect on tissue firmness there by restring of microbes with the antioxidant treatment[20].

Total Soluble Solids (º Brix)

The synergistic effect of antioxidants and modified atmosphere packaging on total soluble solids of guava cv. Allahabad safeda stored at 6 ± 1º C was presented in the Table 8. Highest (11.33) total soluble solids in fruits packed in polypropylene bag with 4 pores + fruits dipped in 50 ppm benzyl adenine. The lowest (10.98) total soluble solids was recorded in the fruits kept under control. The total soluble solids increased from 1th day (9.74) to 20th day (12.24) and thereafter declined from 20th day (12.24) to 25th day (11.57).The total soluble solids increased significantly from 1st day to 20th day, thereafter gradually decreased significantly to reach a minimum on 25th day. However, among the treatments, the fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine was recorded the gradual increase in total soluble solids on all intervals of storage up to 20th day and then decrease on 25th day of storage. Lowest total soluble solids were recorded in fruits kept under control on all intervals of storage. The delayed ripening and decreased rate of starch hydrolysis[18] might have resulted in higher total soluble solids.

Titratable Acidity (%)

Highest titratable acidity (0.35) was in fruits kept under control. The lowest (0.25) titratable acidity was recorded in fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine (table 9). The titrable acidity decreased from 1st day (0.48) to 25th day (0.18). The decrease was more pronounced from 5th day (0.41) to 10th day (0.35). Among all treatments, the fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine recorded lowest titratable acidity up to 25th day of storage, while fruits kept under control recorded highest titratable acidity on all intervals of storage . On 5th day to 25th day, highest titratable acidity was recorded with fruits packed in polypropylene bag with 2 pores + dipping of fruits in 0.1 µM methyl jasmonate which is on par with fruits kept under control . On 1st day to 25th day, on par titratable acidity was recorded in all the treatments except fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine. This might be due to the synergistic effects of modified atmosphere packaging and antioxidants. The decrease in acidity in later stages may be due to utilization of sugars and acids for respiration. Similar decreased acidity was reported by Selvaraj and Pal in sapota fruits.

Brix-Acid ratio

Treated fruits differed significantly with highest (57.03) brix-acid ratio in fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine and the lowest (34.54) brix-acid ratio was recorded in the fruits kept under control (Table 10). Brix-acid ratio increased from 1st day (20.16) to 25th day (56.55). The increase was more pronounced from 15th day (38.54) to 20th day (48.45). In all treatments, the brix-acid ratio was increased irrespective of treatments from 1st day to 25th day of storage. Among all treatments, up to 25th day interval, the highest brix-acid ratio was recorded in the fruits packed in polypropylene bag with 4 pores + 50 ppm benzyl adenine. From 1st day to 25th day, the lowest brix acid ratio was recorded with the fruits kept under control on all intervals of storage. From 1st day to 25th day, on par brix-acid ratio was recorded the fruits packed in polypropylene bag with 4 pores + dipping of fruits in 0.1µM methyl jasmonate and fruits packed in polypropylene bag with 4 pores + 6 mmol oxalic acid on all intervals of storage. The retardation of ripening process and associated biochemical changes[12] and decrease in TSS comprised mostly of sugars, which are subjected to degradation during respiration[2] might have resulted the highest brix-acid ratio.

Ascorbic acid (mg/100g)

Highest (196.62) levels of ascorbic acid content in the fruits packed in polypropylene bags with 4 pores + 50 ppm benzyl adenine (Table 11). The lowest (171.40) levels were recorded in the fruits kept under control. The ascorbic acid increased from 1st day (158.25) to 20th day (215.23) and decreased on 25th day (176.40). Among all treatments, ascorbic acid content increased till 20th day and then decreased. However, the highest ascorbic acid content was recorded in the fruits packed in polypropylene bags with 4 pores + 50 ppm benzyl adenine on all intervals of storage. on 1st day to 25th day of storage lowest ascorbic acid levels was recorded in fruits kept under control. From 1st day to 25th day, on par ascorbic acid levels was recorded the fruits packed with polypropylene bag with 4 pores + 0.1 µM methyl jasmonate, fruits packed with 4 pores+ 500 ppm thiabendazol and fruits packed with 4 pores + 6 mmol oxalic acid on all intervals of storage. Similar results were reported in papaya by Vijay Kumar[21].

Table 1: Synergistic effects of antioxidants and modified atmosphere packaging on physiological loss in weight (PLW) (%) during storage of guava cv. Allahabad safeda at 6 ± 1° C.

Treatments	Days after harvest					Mean
	5	10	15	20	25	
T_1	0.53	1.30	2.30	2.75	3.30	2.03^e
T_2	0.52	1.28	2.40	2.80	3.35	2.07^d
T_3	0.60	1.40	2.15	2.60	3.26	2.02^e
T_4	0.60	1.39	2.30	2.69	3.43	2.08^d
T_5	0.49	1.10	1.98	2.40	3.05	1.80^f
T_6	0.63	1.38	2.46	2.79	3.40	2.13^c
T_7	0.59	1.40	2.50	2.78	3.45	2.14^c
T_8	0.62	1.42	2.55	2.90	3.50	2.19^b
T_9	1.54	2.66	3.44	4.25	5.50	3.47^a
Mean	0.68^e	1.48^d	2.45^c	2.88^b	3.58^a	

	F -test	S.Em ±	CD at 5 %
Treatments	**	0.012	0.036
Days	**	0.009	0.027
Treatments × Days	**	0.028	0.081

Table 2: Synergistic effects of antioxidants and modified atmosphere packaging on fruit firmness ($kg.cm^{-2}$) during storage of guava cv. Allahabad safeda at 6 ± 1°C

Treatments	**Days after harvest**					**Mean**
	5	**10**	**15**	**20**	**25**	
T_1	8.42	7.56	6.38	4.88	2.95	**6.03^b**
T_2	8.41	7.50	6.38	4.75	2.80	**5.94^c**
T_3	8.38	7.47	6.33	4.55	2.85	**5.91^c**
T_4	8.38	7.45	6.34	4.72	2.75	**5.92^c**
T_5	8.55	7.78	6.56	4.95	3.10	**6.18^a**
T_6	8.39	7.46	6.32	4.52	2.75	**5.88^d**
T_7	8.35	7.42	6.29	4.48	2.64	**5.83^e**
T_8	8.33	7.39	6.27	4.45	2.62	**5.81^e**
T_9	7.51	6.18	5.23	3.15	1.05	**4.62^f**
Mean	**8.30^a**	**7.35^b**	**6.22^c**	**4.49^d**	**2.61^e**	

	F -test	**S.Em ±**	**CD at 5 %**
Treatments	**	0.012	0.036
Days	**	0.009	0.027
Treatments × Days	**	0.028	0.081

Table 3: Synergistic effects of antioxidants and modified atmosphere packaging on chilling injury (skin scald) during storage of guava cv. Allahabad safeda at 6 ± 1º C

Treatments	Days after harvest						Mean
	5	10	15	20	25	30	
T_1	1.10	1.78	2.10	2.75	3.15	3.60	**2.41^c**
T_2	1.15	1.75	2	2.60	3.10	3.50	**2.35^d**
T_3	1.15	1.78	2.17	2.78	3.20	3.70	**2.46^b**
T_4	1.14	1.78	2.17	2.75	3.18	3.69	**2.45^b**
T_5	1	1.40	1.86	2.30	2.90	3.26	**2.12^e**
T_6	1	1.70	2.15	2.80	3.15	3.55	**2.39^d**
T_7	1	1.68	2.18	2.82	3.18	3.58	**2.40^c**
T_8	1.10	1.76	2.05	2.63	3.12	3.55	**2.36^d**
T_9	1.17	2.25	3.40	3.98	4.30	4.92	**3.33^a**
Mean	**1.09^f**	**1.76^e**	**2.23^d**	**2.82^c**	**3.25^b**	**3.70^a**	

	F –test	S.Em ±	CD at 5 %
Treatments	**	0.011	0.032
Days	**	0.009	0.026
Treatments × Days	**	0.028	0.079

Table 4: Synergistic effects of antioxidants and modified atmosphere packaging on electrolyte leakage (%) during storage of guava cv.Allahabad safeda at 6 ± 1º C

Treatments	Days after harvest							Mean
	1	5	10	15	20	25	30	
T_1	4.45	5.51	6.82	8.10	8.72	9.30	10.83	**7.67^c**
T_2	4.50	5.54	6.80	8.15	8.68	9.28	10.78	**7.67^c**
T_3	4.68	5.64	6.90	8.30	8.81	9.33	11.10	**7.82^b**
T_4	4.65	5.68	6.92	8.28	8.78	9.30	11	**7.80^b**
T_5	4.05	5.15	6.26	7.50	8.30	9.05	10.10	**7.19^e**
T_6	4.20	5.35	6.56	7.94	8.68	9.20	10.82	**7.53^d**
T_7	4.18	5.30	6.58	7.89	8.66	9.25	10.79	**7.52^d**
T_8	4.21	5.31	6.56	7.86	8.71	9.28	10.78	**7.53^d**
T_9	5.45	6.35	8.18	10.30	12.10	13.48	14.86	**10.10^a**
Mean	**4.48^g**	**5.53^f**	**6.84^e**	**8.25^d**	**9.04^c**	**9.71^b**	**11.22^a**	

	F- test	S.Em ±	CD at 5%
Treatments	**	0.010	0.030
Days	**	0.009	0.026
Treatments × Days	**	0.028	0.081

Table 6: Synergistic effects of antioxidants and modified atmosphere packaging on shelf life (in days) during storage of guava cv. Allahabad safeda at 6 ± 1º C

Treatments	Shelf life(Days)
T_1	26.28[c]
T_2	26.33[c]
T_3	25.33[d]
T_4	25.30[d]
T_5	29.45[a]
T_6	28.38[b]
T_7	28.35[b]
T_8	28.40[b]
T_9	20[e]
Mean	26.53
F-test	**
S.Em ±	0.41
CD at 5% Level	0.86

Table 5: Synergistic effects of antioxidants and modified atmosphere packaging on ripening (in days) during storage of guava cv. Allahabad safeda at 6 ± 1º C

Treatments	Shelf life(Days)
T_1	16.12 [c]
T_2	16.18[c]
T_3	15.42[c]
T_4	15.35[c]
T_5	20.10 [a]
T_6	18.23[b]
T_7	18.18[b]
T_8	18.15[b]
T_9	9.25[d]
Mean	16.33
F-test	**
S.Em ±	0.577
CD at 5% Level	1.73

Table 7: Synergistic effects of antioxidants and modified atmosphere packaging on organoleptic evaluation (score) during storage of guava cv. Allahabad safeda at 6 ± 1º C

Treatments	Days after harvest							Mean
	1	5	10	15	20	25	30	
T_1	4.08	6.10	7.35	7.95	8.10	6.40	4.05	**6.29[c]**
T_2	4.05	6.15	7.38	7.98	8.15	6.35	4	**6.29[c]**
T_3	4.07	6	7.30	7.75	8	6.20	3.90	**6.17[e]**
T_4	4.08	6.03	7.35	7.80	8.30	6.15	4.03	**6.24[d]**
T_5	4.10	6.20	7.45	8.10	8.30	6.70	4.20	**6.43[a]**
T_6	4.10	6.15	7.35	7.98	8.20	6.60	4.10	**6.35[b]**
T_7	4.10	6.20	7.40	8.00	8.30	6.50	4.05	**6.36[b]**
T_8	4.10	6.24	7.32	8.10	8.30	6.45	4.10	**6.37[b]**
T_9	4.05	5.80	6.92	7.30	7.70	4.35	2.10	**5.46[f]**
Mean	**4.08[f]**	**6.09[e]**	**7.31[c]**	**7.94[b]**	**8.15[a]**	**6.18[d]**	**3.83[g]**	

	F- test	S.Em ±	CD at 5%
Treatments	**	0.010	0.030
Days	**	0.009	0.026
Treatments × Days	**	0.028	0.081

Table 8: Synergistic effects of antioxidants and modified atmosphere packaging on total soluble solids (^{0}Brix) during storage of guava cv. Allahabad safeda at 6 ± 1^{o} C

Treatments	Days after harvest						Mean
	1	5	10	15	20	25	
T_1	9.75	10.43	11.30	11.68	12.15	10.76	**11.18^{c}**
T_2	9.72	10.40	11.25	11.66	12.18	10.74	**11.16^{c}**
T_3	9.74	10.38	11.24	11.64	12.14	10.73	**11.15^{c}**
T_4	9.73	10.36	11.24	11.65	12.16	11.74	**11.14^{d}**
T_5	9.81	10.67	11.45	11.87	12.40	11.80	**11.33^{a}**
T_6	9.74	10.63	11.40	11.85	12.36	11.75	**11.29^{b}**
T_7	9.75	10.60	11.38	11.83	12.35	11.75	**11.28^{b}**
T_8	9.76	10.61	11.39	11.84	12.34	11.76	**11.28^{b}**
T_9	9.70	10.95	11.30	11.80	12.05	10.10	**10.98^{e}**
Mean	**9.74^{f}**	**10.56^{e}**	**11.33^{d}**	**11.76^{b}**	**12.24^{a}**	**11.57^{c}**	
	F –test		**S.Em ±**		**CD at 5 %**		
Treatments	**		0.012		0.033		
Days	**		0.009		0.027		
Treatments × Days	**		0.029		0.080		

Table 9: Synergistic effects of antioxidants and modified atmosphere packaging on Titratable acidity (%) during storage of guava cv. Allahabad safeda at 6 ± 1^{o} C

Treatments	Days after harvest						Mean
	1	5	10	15	20	25	
T_1	0.48	0.43	0.35	0.30	0.26	0.20	**0.33^{b}**
T_2	0.48	0.45	0.38	0.32	0.28	0.22	**0.35^{a}**
T_3	0.47	0.44	0.36	0.31	0.24	0.21	**0.33^{b}**
T_4	0.48	0.43	0.36	0.29	0.23	0.20	**0.33^{b}**
T_5	0.45	0.35	0.25	0.20	0.16	0.11	**0.25^{d}**
T_6	0.47	0.38	0.29	0.22	0.18	0.15	**0.28^{c}**
T_7	0.49	0.39	0.30	0.23	0.19	0.16	**0.29^{c}**
T_8	0.49	0.40	0.29	0.22	0.18	0.14	**0.29^{c}**
T_9	0.49	0.44	0.37	0.30	0.26	0.22	**0.35^{a}**
Mean	**0.48^{a}**	**0.41^{b}**	**0.35^{c}**	**0.27^{d}**	**0.22^{e}**	**0.18^{f}**	
	F -test		**S.Em ±**		**CD at 5 %**		
Treatments	**		0.003		0.007		
Days	**		0.002		0.006		
Treatments × Days	**		0.006		0.019		

Table 10: Synergistic effects of antioxidants and modified atmosphere packaging on brix-acid ratio during storage of guava cv. Allahabad safeda at 6 ± 1^{o} C

Treatments	Days after harvest						Mean
	1	5	10	15	20	25	
T_1	20.31	24.25	32.29	38.93	46.73	58.8	**36.89^{e}**
T_2	20.25	23.11	29.60	36.43	43.5	53.36	**34.38^{f}**
T_3	20.72	23.59	31.22	37.54	50.58	55.85	**36.58^{e}**
T_4	20.27	24.67	31.64	40.82	53.65	58.8	**38.31^{d}**
T_5	21.8	30.48	45.8	59.35	77.5	107.27	**57.03^{a}**
T_6	20.72	27.97	39.31	53.86	68.66	78.33	**48.14^{b}**
T_7	19.89	27.17	37.93	51.43	65	73.43	**45.81^{c}**
T_8	19.92	26.52	39.28	53.81	68.55	84	**48.68^{b}**
T_9	19.80	24.88	30.54	39.33	46.35	46.36	**34.54^{f}**
Mean	**20.16^{f}**	**24.41^{e}**	**31.68^{d}**	**38.54^{c}**	**48.45^{b}**	**56.55^{a}**	
	F -test		**S.Em ±**		**CD at 5 %**		
Treatments	**		0.47		1.32		
Days	**		0.39		1.08		
Treatments × Days	**		1.15		3.24		

Table 11: Synergistic effects of antioxidants and modified atmosphere packaging on ascorbic acid (mg 100 g^{-1}) during storage of guava cv.Allahabad safeda at 6 ± 1° C

Treatments	Days after harvest						Mean
	1	5	10	15	20	25	
T_1	156.40	170.24	186.75	198.20	210.33	173.45	**182.56^c**
T_2	157.35	171.30	187.60	197.15	213.20	172.52	**182.35^c**
T_3	158.22	172.15	187.73	198.82	215.30	175.30	**184.58^c**
T_4	157.20	173.35	186.82	197.30	214.42	172.66	**183.62^c**
T_5	165.10	179.15	195.22	210.45	236.69	189.78	**196.62^a**
T_6	159.20	175.31	188.65	200.10	220.33	179.40	**187.17^b**
T_7	160.43	176.10	187.82	202.13	218.80	178.90	**187.42^b**
T_8	160.78	177.33	189.45	205.10	217.52	177.82	**188^b**
T_9	156.60	161.30	173.42	186.10	193.52	164.50	**171.40^d**
Mean	**158.25^f**	**172.95^e**	**187.05^c**	**199.48^b**	**215.23^a**	**176.40^d**	

	F –test	S.Em ±	CD at 5 %
Treatments	**	0.75	2.11
Days	**	0.61	1.72
Treatments × Days	*	1.84	5.17

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